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Section VI. Carbon foils

A FACILITY FOR PRODUCTION OF IMPROVED CARBON FOILS

John O. STONER Jr, Stanley BASHKIN and Scott M. HITCHCOCK

*The Arizona Carbon Foil Company *, 4152 E. Sixth Street, Tucson, AZ 85711, USA and*
Physics Department, University of Arizona, Tucson, AZ 85721, USA

Tests of an apparatus intended for the production of cracked-hydrocarbon foils have begun. Such foils are used for strippers, windows, and filters for both soft X-rays and the near infrared. Thus far, pilot quantities of such foils have been produced with various substrate materials; full-scale operation is expected by late 1984.

1. Introduction

Carbon foils produced by cracking hydrocarbon gases have been used as strippers in accelerators for several years, since it was shown [1–3] that they can have greater resistance than conventional foils to damage by beam particles.

At the moment, no commercial source for these stripper foils exists. While researchers at several other laboratories now make such foils for their own use [4–11], others have been unsuccessful. Many requests to provide this product have been received by the authors.

In order to provide suitable carbon foils prepared by the cracking process to the research community, the supplier must be able to make large quantities of foils, each with known surface density on substrates that are well-characterized, and to make foils that are stable in storage and shipment, easy to float off and mount, and that have a noncontaminating parting agent. This has already required a fair amount of developmental work by many investigators, and promises to require still more. An apparatus to provide the required carbon foils has now been built by the authors and is presently being tested.

2. Apparatus

The apparatus was closely modeled after that constructed by Tait et al. [1], except for the details noted below.

The coating chamber (fig. 1) is cylindrical with an interior diameter of 293 mm and a height of 475 mm. The volume of the chamber is about 32 l. It is largely constructed of Pyrex glass and aluminum with neoprene gaskets, coated lightly with either silicone or Apiezon

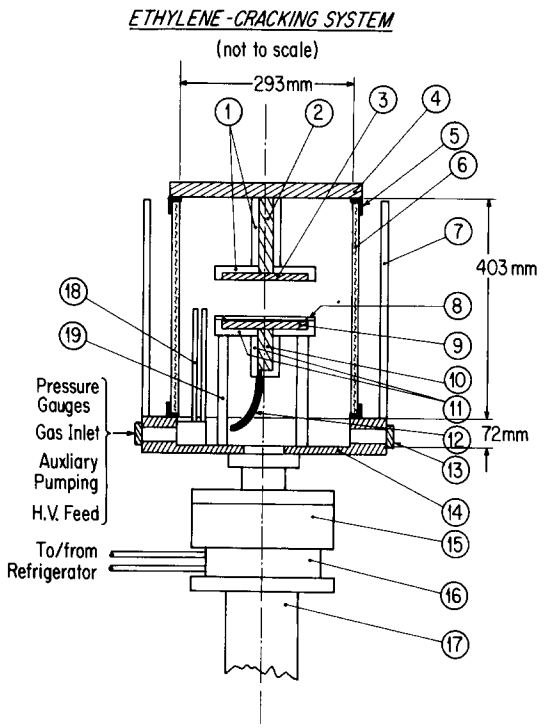

Fig. 1. Apparatus (not to scale) used to produce cracked-hydrocarbon foils. 1) Polycarbonate insulators, 2) anode support post (aluminum), 3) anode (brass), 4) cover plate (grounded), 5) neoprene gasket, 6) Pyrex glass vacuum jar, 7) plastic implosion shield, 8) electrode clamp (polycarbonate), 9) cathode (brass) and substrate, 10) post for cathode connection (brass), 11) polycarbonate insulators, 12) insulated high-voltage cable, 13) port cover (steel), 8 required, 14) aluminum ring and baseplate, 15) gate valve (10-cm aperture), 16) refrigerated baffle, 17) oil diffusion pump (10-cm aperture), 18) gas-inlet tubulation (polycarbonate), 19) anode support (3 required). Pressure gauging, gas inlet connection, auxiliary pumping connection, and high-voltage feedthrough are made via port covers (part 13).

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grease. The base of the chamber contains a 100-mm-diameter aperture, sealed by a gate valve, that leads to the pumping system.

Four methods for pumping the chamber have been investigated. Initial plans called for the use of a 400 l/s turbomolecular pump. However, the pump failed catastrophically after a few minutes' operation. Next, a 600 l/s diffusion pump, with an associated trap cooled with liquid nitrogen, and an untrapped rotary (mechanical) foretrap were tried separately. Both worked satisfactorily for the initial vacuum tests and production of pilot quantities of foils, although the ultimate vacuum for the rotary pump alone was not adequate to guarantee reproducible foil properties. The final design incorporates a diffusion pump with a Freon-12-cooled baffle. The use of liquid nitrogen must be avoided because many hydrocarbon gases, particularly ethylene, have vapor pressures in the 0.1 Pa range at liquid-nitrogen temperature; a liquid-nitrogen-cooled trap on which some ethylene has condensed serves as a virtual leak instead of a trap for this gas.

The electrodes (fig. 2) are constructed of brass with polycarbonate shielding to limit the discharge primarily to the space between them. The high voltage for the cathode (to which the target substrate is clamped), the gas inlet, and tubulation from the pressure sensors are brought into the system through ports in an aluminum ring.

The power supply connected to the cathode has a current capability of 0.5 A at 5000 V. A current-limiting resistor (2000 Ω, 200 W) is placed in series between the power supply and the cathode to stabilize the discharge.

At present, provisions have been made for the control of only one gas in the chamber at any given time. Either argon or ethylene is admitted to a manifold; its exit to the discharge chamber is controlled by a servo-controlled valve (Vacuum General #77-10M) and a shutoff valve. A capacitance manometer (Vacuum-General CMH-01) with an operating range of 0–133 Pa senses the pressure in the chamber; a signal from the manometer controls the valve so that while the pump is operating on the system, any preset pressure in the operating range can be maintained indefinitely. An auxiliary Pirani gauge provides a readout of the pressure over a wider range.

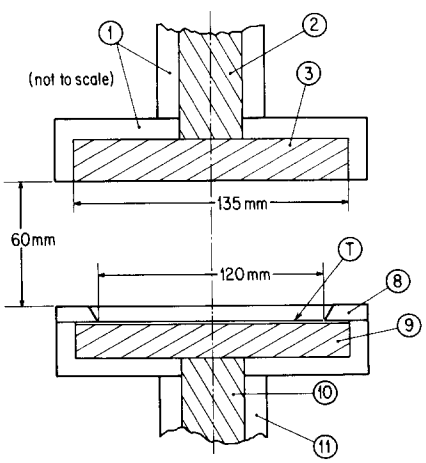

Fig. 2. Electrode assembly (not to scale). T = substrate to be coated with carbon; other labels are defined in the caption of fig. 1.

3. Operation

Several different substrate materials are being tested. Various investigators have used plated metal discs cut from ferrotype plates; these work well but are increasingly more difficult to obtain. In addition, plain glass microscope slides and slides precoated with aluminum or gold have been used by the authors. To date, the metal-coated glass substrates have not worked well; the cracking process partially removes the metal coating, and a uniform carbon layer does not form in the voltage and pressure ranges tried so far.

Starting with either a ferrotype plate or several clean microscope slides, an evaporated layer of NaCl or an airbrushed layer of RBS-25 (made by Chemical Concentrates, Ltd.) is deposited as a parting agent. The advantage of using the latter is that it does not recrystallize when stored at high relative humidity. The coated substrate is clamped on the cathode electrode by a plastic ring. Where microscope slides are to be coated, a perforated steel shield plate covers them, allowing circular regions of 12 mm diameter to be coated. Larger areas are not coated uniformly.

The sealed system is then pumped to well below 1.3 Pa and, while pumping continues, ethylene is admitted to raise the pressure to 11 Pa. A voltage of −2500 V is then applied to the cathode; the anode is maintained at ground potential. Typically, a current density of 0.5–1.0 mA/cm^2 is maintained for 5 s. The voltage is reduced to zero, and the cathode is allowed to cool, after which the process may be repeated as needed to obtain the desired foil thickness.

4. Results

The procedure described has been used for coating conventional substrates as well as wax, polycarbonate, and polyester sheets. Preliminary tests [12] show that the apparatus works satisfactorily and that foils made by it are long-lived in an accelerator beam. Efforts to produce well-characterized and reproducible carbon foils with the system described are continuing.

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